

CASE STUDY: INVESTIGATING A RAIL ROLLOVER DERAILMENT

FRA Track Safety Symposium
St. Louis, MO
April 6, 2022

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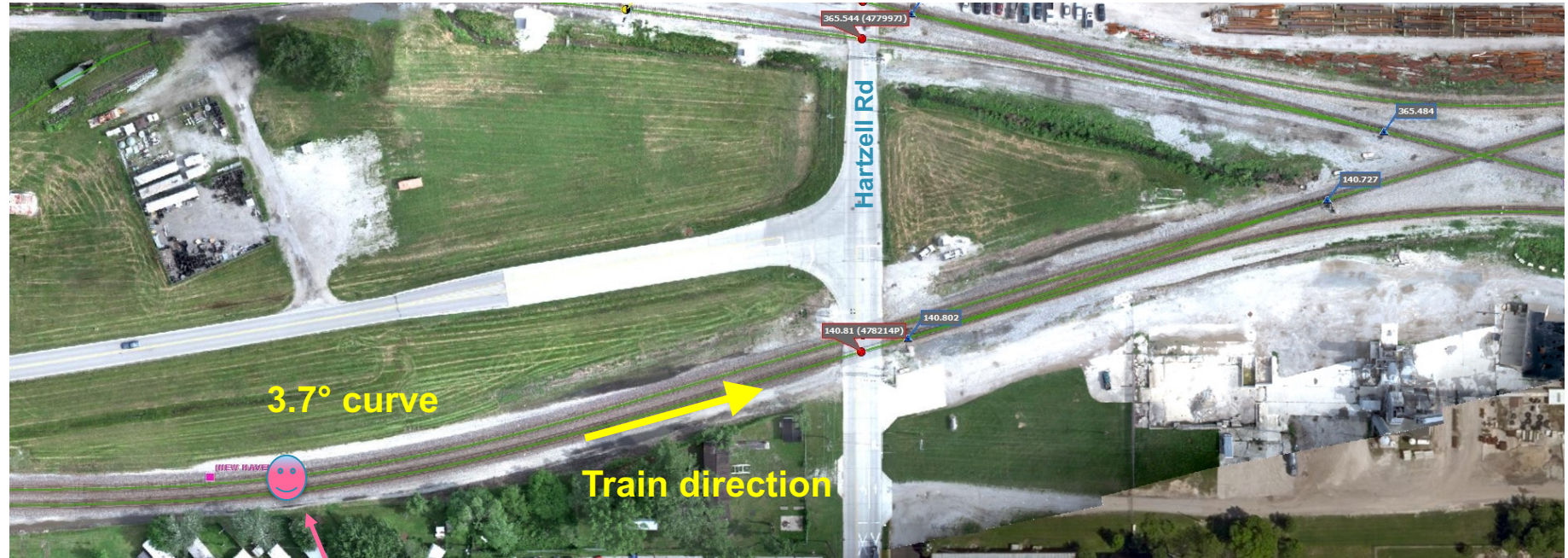
THE SET-UP

- CP NE, Ft Wayne, IN
- August 18, 2017
- Train 20A
 - 2 locomotives
 - 36 loads (88 double-stack platforms)
 - 5921 tons / 5894 feet
 - train was moving at 16 mph in notch 3
- 3.7° curve, 3" elevation



Looking from POD east, in direction of train movement (after post-derailment trackwork)

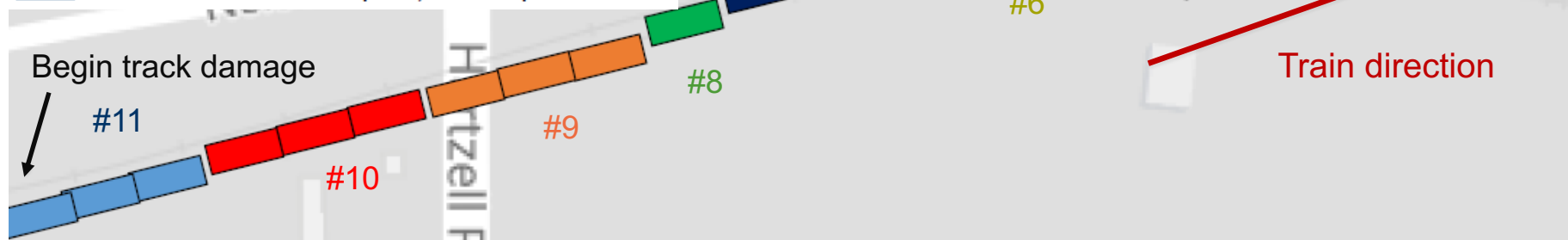
GIS IMAGE OF DERAILMENT SITE



Camera location in slide 2

WHICH CARS DERAILED?

<u>Position</u>	<u>Description</u>
#3	DTTX 787816 3 pack, trail truck only
#4	DTTX 727311 3 pack, all
#5	DTTX 468325 1 pack, all
#6	DTTX 659439 1 pack, all
#7	DTTX 766169 3 pack, all
#8	DTTX 467061 1 pack, all
#9	DTTX 620335 3 pack, all
#10	BNSF 255199 3 pack, all
#11	DTTX 788577 3 pack, all except trail truck



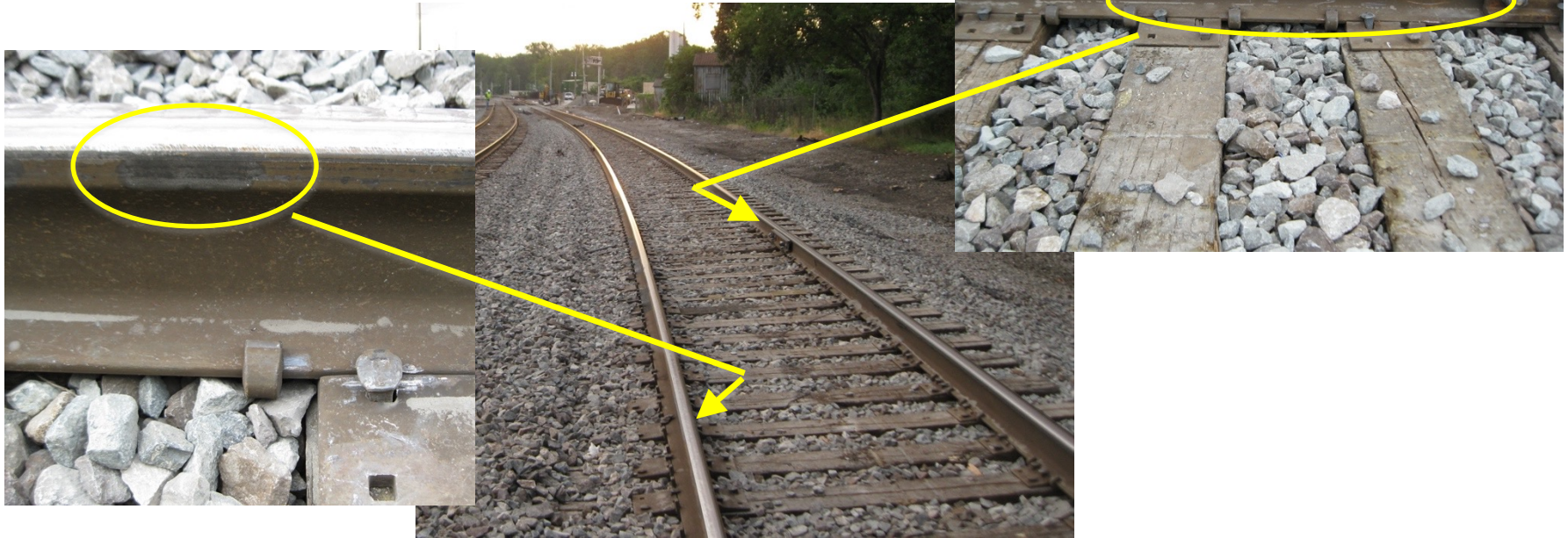
WHEN LOOKING FOR A DERAILMENT CAUSE, WHAT ARE THE TWO MOST IMPORTANT QUESTIONS TO ANSWER?

1. What was the POD?
2. What was the first car to derail?



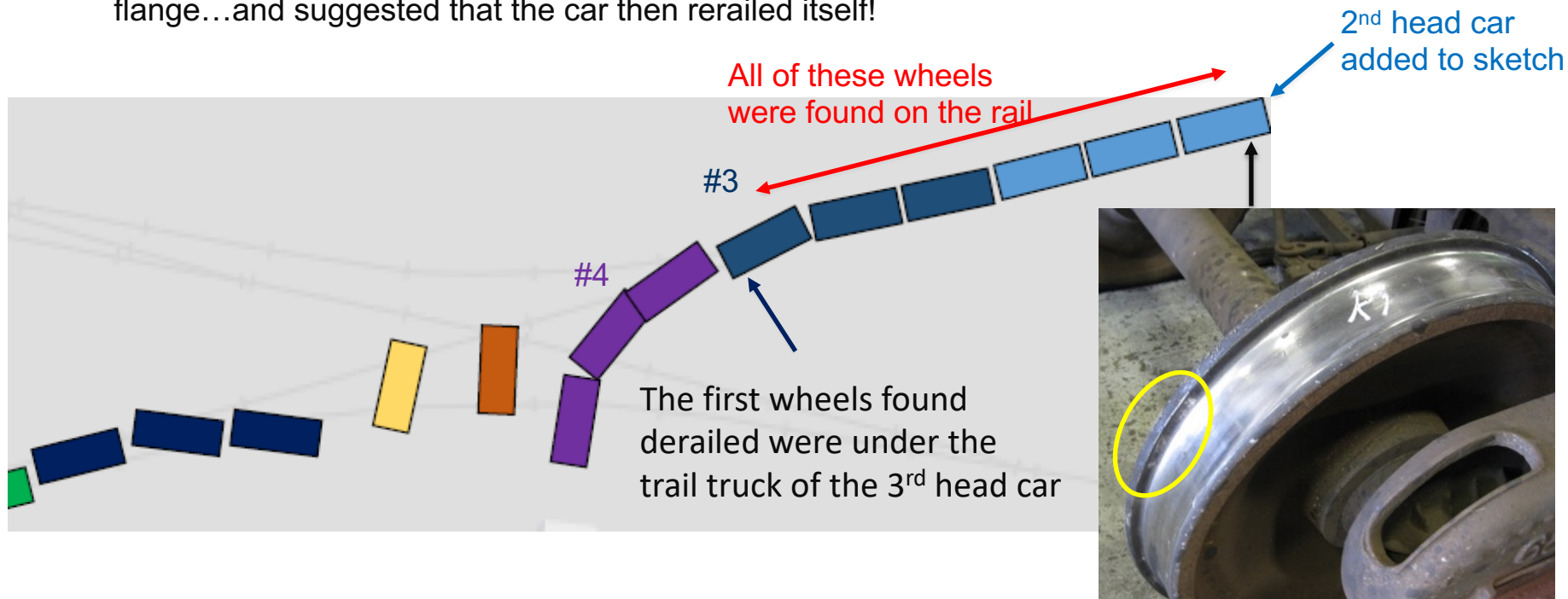
WHAT WAS THE POD?

The derailment committee identified an area where a low-side wheel dropped in and the high rail showed a flange mark on the web.

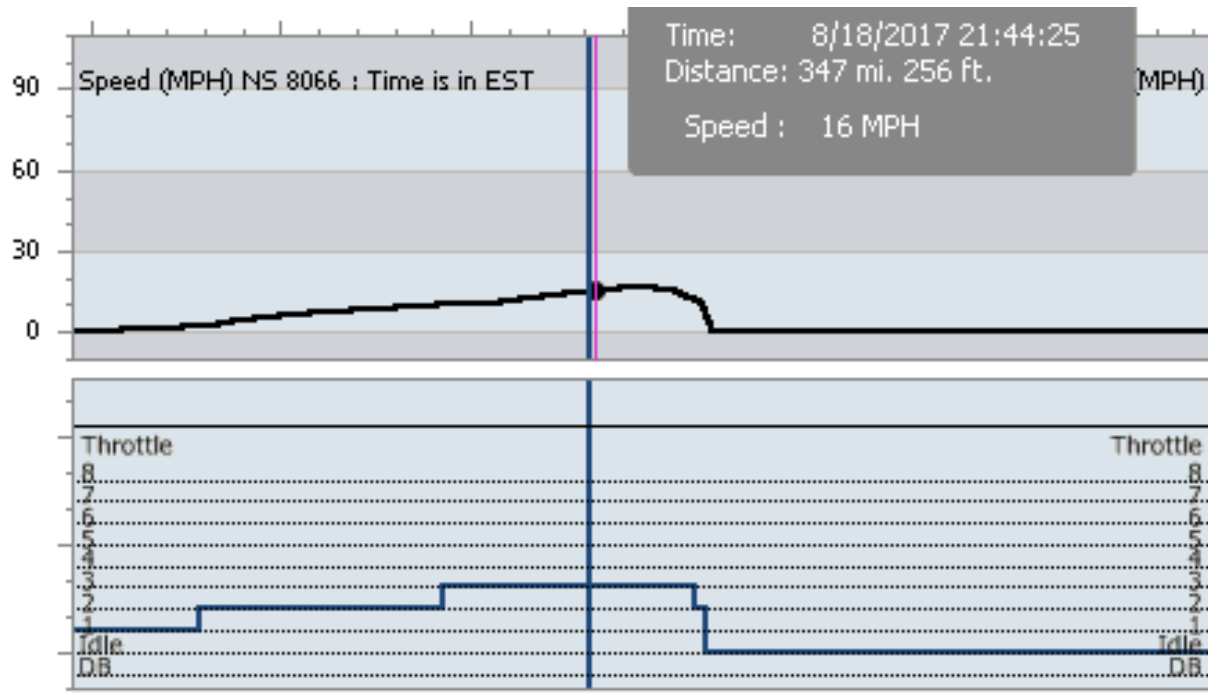


WHAT WAS THE FIRST CAR TO DERAIL?

Initially, Mechanical identified the 2nd car / lead truck as the first to derail because of white marks on a wheel flange...and suggested that the car then rerailed itself!

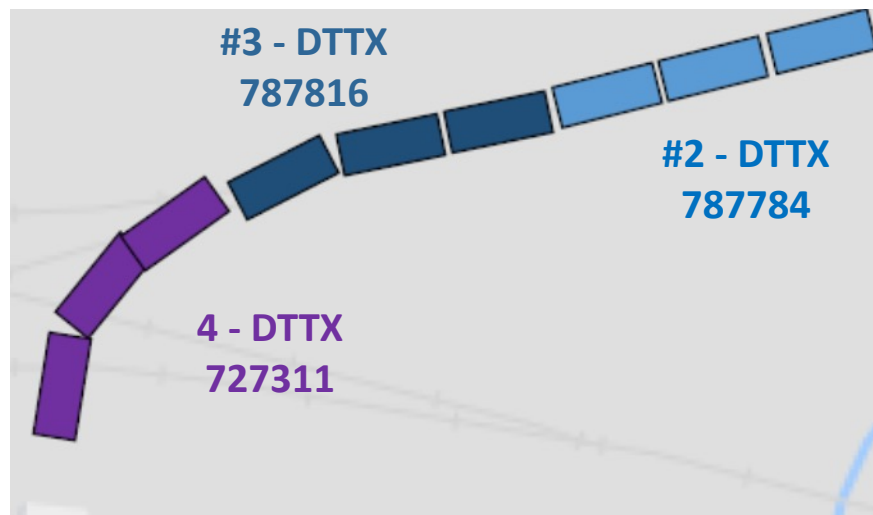


TRANSPORTATION REVIEW – EVENT RECORDER



- The cursor marks when the lead locomotive was just east of Hartzell Rd.
- Speed was 16 mph and climbing gradually.
- Throttle was in notch 3.

MECHANICAL REVIEW – CAR INSPECTION



2nd head car, **DTTX 787784**, lead truck (the one thought to have derailed and then rerailed itself) inspected in car shop. No exceptions.

3rd head car **DTTX 787816**, trail truck inspected in car shop, wheels replaced due to minor derailment damage. No other exceptions.

4th head car **DTTX 727311**, all four trucks derailed, with severe damage to the wheels under the two intermediate (C and D) trucks. Car was not re-railed. A thorough inspection was not possible.

TRACK REVIEW – TRACK GEOMETRY

Curvature – left axis

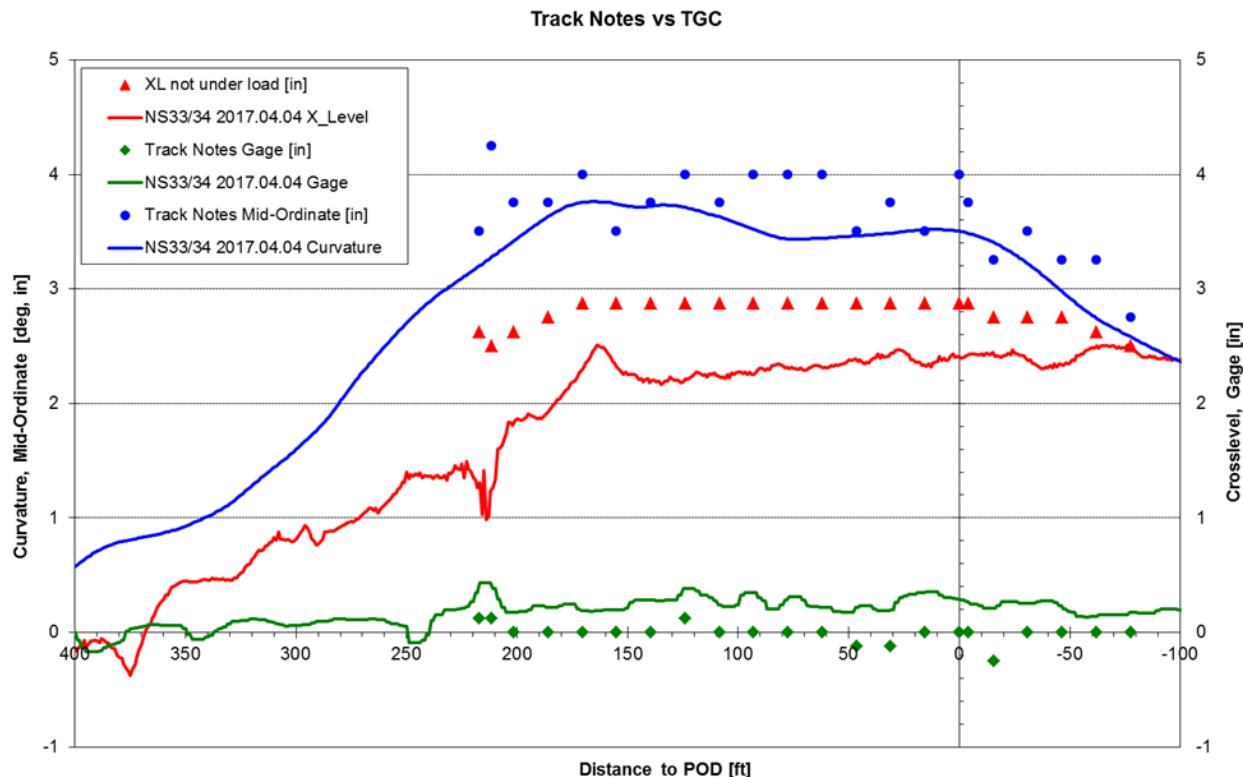
X-level and gage – right axis

“0” on horizontal axis marks the POD.

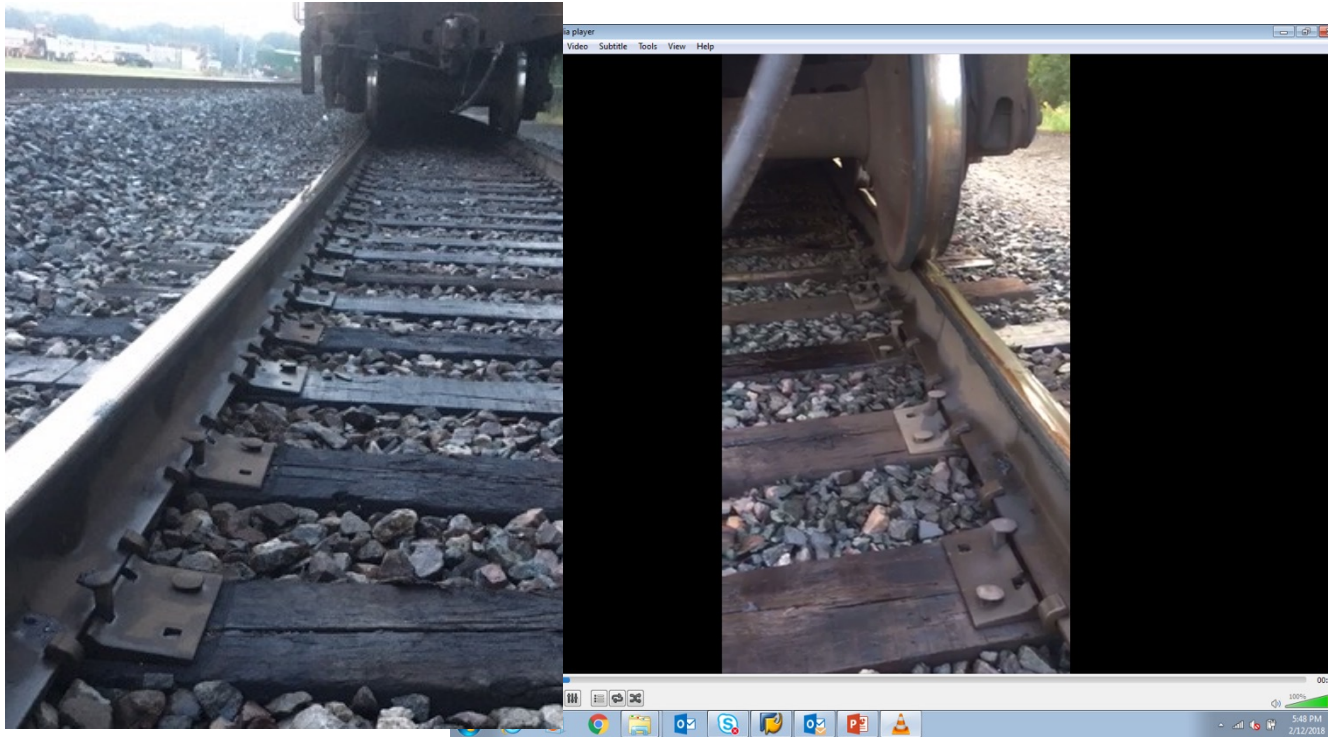
Points: Gage, alignment & crosslevel from derailment track notes (Aug 18, 2017)

Lines: Same parameters from April 4, 2017 track geometry car test

Conclusion: line, surface and gage all look good!



TRACK REVIEW – CONDITIONS BEFORE POD



This wheelset is under the trail truck of last derailed car. This truck stopped short of the POD

Low rail on left

High rail on right

Note raised spikes on both rails

VIDEO TAKEN BY DIVISION ENGINEER



Observations

- High rail - spikes lifted for a short distance prior to POD.
- Low rail - spikes lifted for a longer distance prior to POD.

TRACK REVIEW – WHEEL / RAIL CONTACT



Three unusual conditions were noted on the low rail prior to the POD:

1. Scuff marks on field side of the head
2. Wheel flange contact on the gage face
3. Evidence that rail had been canting out under load

THE DERAILMENT COMMITTEE'S INITIAL ASSESSMENT

Train handling

- Steady draft, accelerating at 16 mph in throttle notch 3. Speed slowed to 10 mph as train was dragged down by derailed cars, then emergency brake application. Train handling determined not to be a factor.

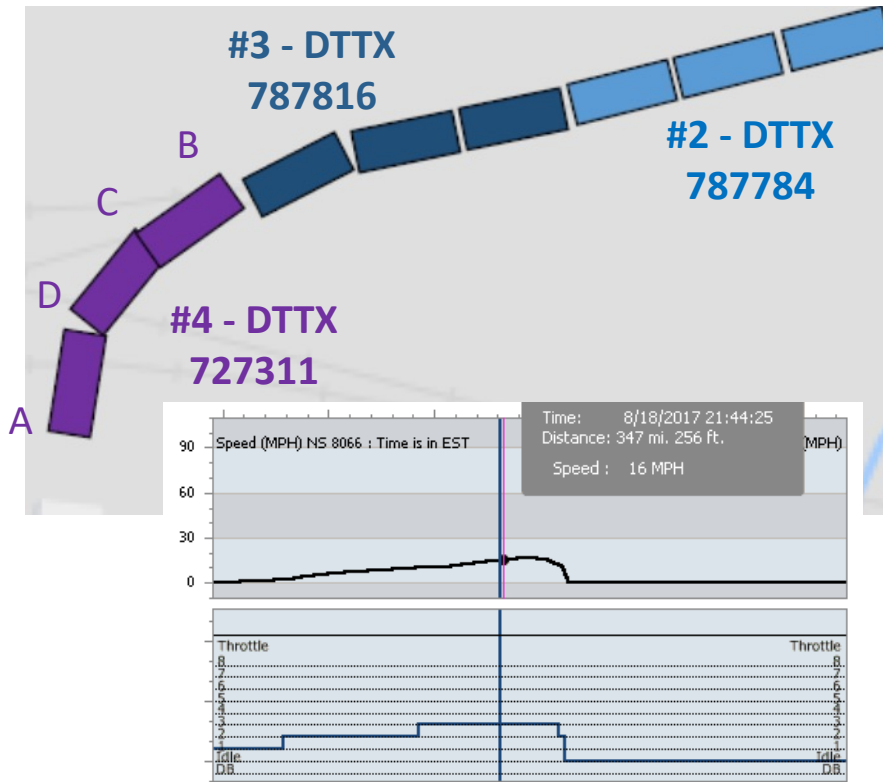
Mechanical

- Identified lead truck of 2nd car as first to derail. Other than wheel damage due to derailment, no mechanical defects were noted on 2nd, 3rd or 4th head cars.

Track

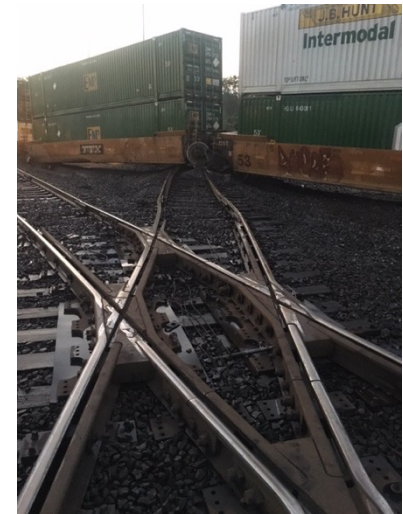
- No exceptions to alignment (3.7° curve), elevation (consistent 2-7/8"), or gage (consistent 56-3/4").
- No exceptions to low rail (136# / 2016) or high rail (worn 132# / 1978).
- Circumstances involved low rail canting out and high rail rolling over.
- Unusual marks on low rail – scuff marks, flange contact on gage face & dynamic cant.

SO WHAT HAPPENED?



What is a key piece of evidence?

4th head car DTTX 727311, all four trucks derailed, with **severe damage to the wheels under the two intermediate (C and D) trucks.**



WHY DID MECHANICAL IDENTIFY THE 2ND CAR / LEAD TRUCK?

- Conclusion: This truck did not derail



Suspect: 2nd head car, lead truck



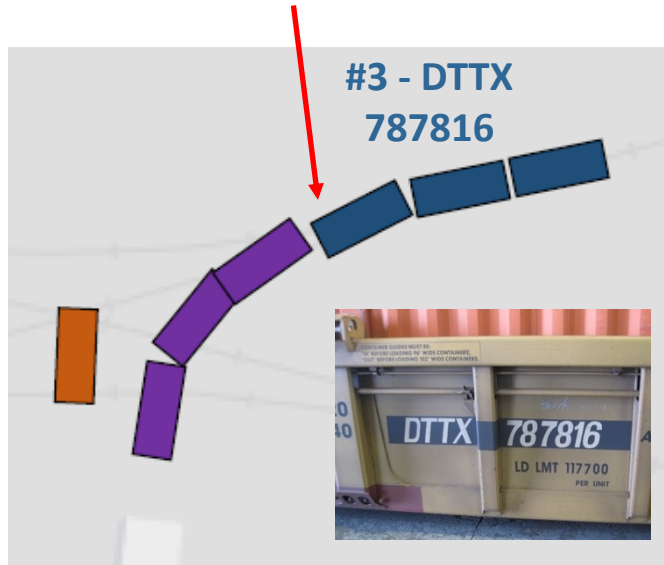
R1 showed several white marks on the flange. During a car shop inspection, however, no evidence was found on the tread or flange tip that indicated that the wheel had been on the ground.



None of the other wheel treads or flanges showed evidence of derailment damage.

■ LET'S LOOK AT THE 1ST DERAILED CAR – DTTX 787816

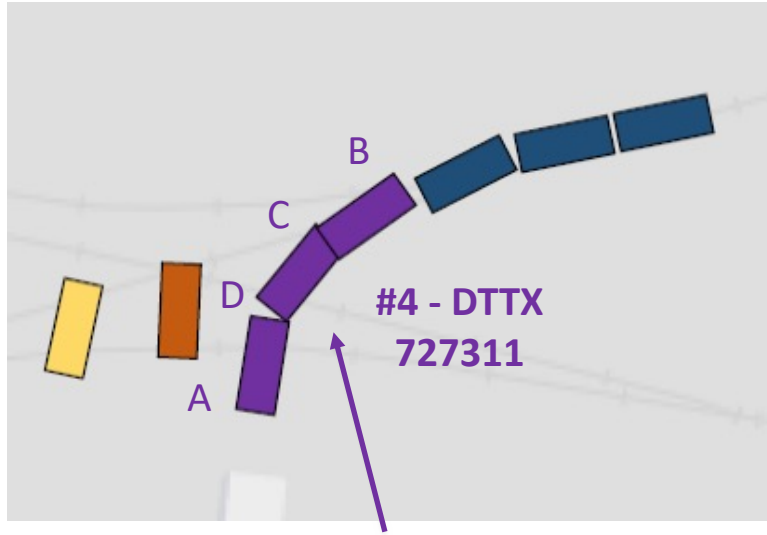
The first derailed wheels were under the trail truck of the 3rd car.



These wheels show some flange contact with the ground, but not enough to have been the first to derail (they would have run over 2 turnouts and a diamond).



HOW ABOUT THE 2ND DERAILED CAR – DTTX 727311?



Wheels under all
4 trucks derailed

The B (lead) and C platforms are shown below.
Between them is the C truck. The D truck and the
A platform were separated by the derailment.



WHAT DID THE WHEELS UNDER B TRUCK LOOK LIKE?



L1 and R1 showed minimal damage



L2 and R2 also showed minimal damage



WHAT DID THE WHEELS UNDER C TRUCK LOOK LIKE?



L3 and R3 showed moderate damage.

Bottom (left to right):

L4, L4 flange, R4, and R4 tread (with asphalt deposit from Hartzell Rd crossing).



WHAT DID THE WHEELS UNDER D TRUCK LOOK LIKE?



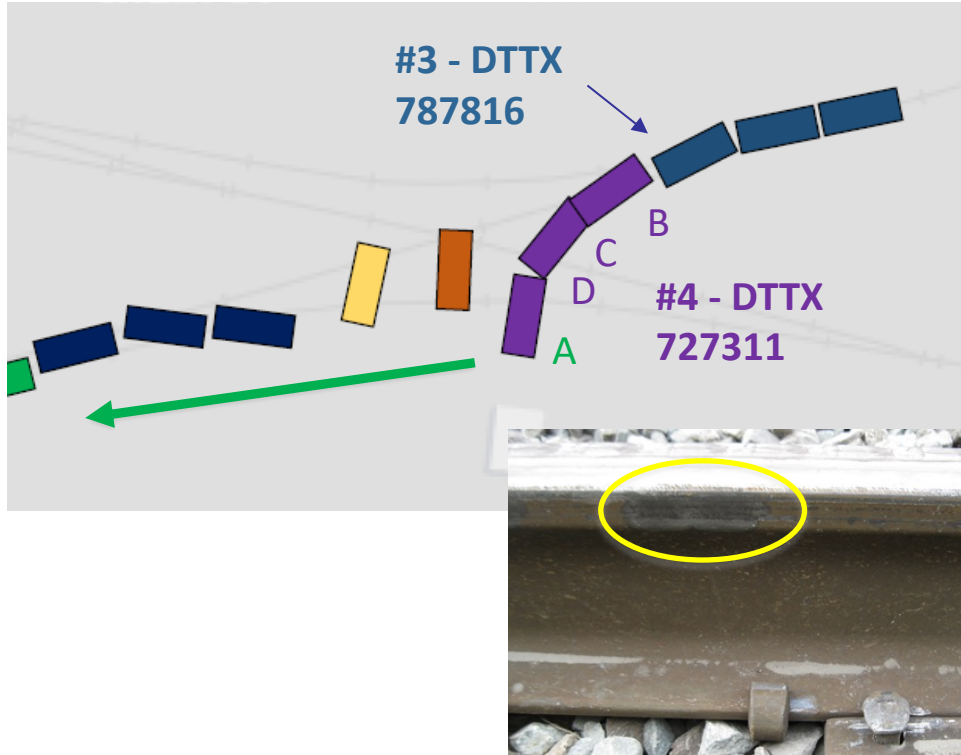
L5 & R5

Note asymmetric wear – each axle has a wheel with a worn flange and hollow tread, and a wheel with a full flange and normal tread.



L6, L6 flange & R6

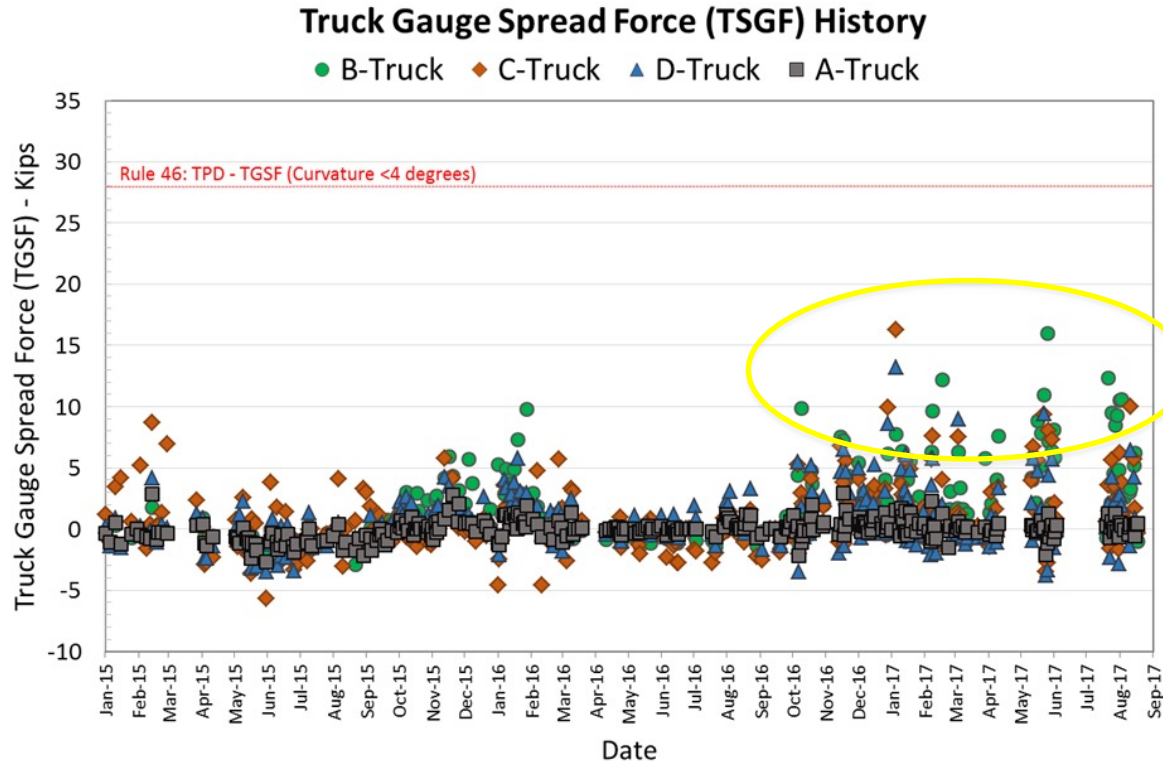
DERAILMENT EXPLANATION (AND ANSWERS TO OUR TWO QUESTIONS)



Based on damage to wheels 3 & 4 (truck C) and 5 & 6 (truck D), we concluded that:

1. Intermediate trucks **C** and **D** under the 4th car **DTTX 727311** were the first to derail, as a result of rolled rail.
2. These derailed trucks subsequently pulled off lead truck **B**, which then pulled off the trail truck of the 3rd car **DTTX 787816**.
3. All following trucks derailed due to the rolled rail.
4. The POD was identified at the first drop-in mark on the low-rail.

WILD DATA FOR DTTX 727311



Gage-spreading force = sum of lateral wheel forces.

B and C trucks, and to some extent D truck, became elevated on a sustained basis in late 2016.

This plot does not differentiate by leading end or load/empty status.

MARKS ON THE RAIL (1)

The field side of the low rail showed a series of scuff marks from beginning of curve to the POD



What wheel characteristic is likely to cause this type of scuff mark?

MARKS ON THE RAIL (2)

The low rail gage face showed evidence of wheel flange contact from the beginning of the curve to the POD.



Entrance to curve, 350 ft. before POD



Station 16



Station 6

In order for wheel flanges to contact the gage face of a low rail, the rail must be canted out!

MARKS ON THE RAIL (3)

The low rail showed additional evidence of dynamic cant from beginning of the curve to the POD.



Derailment Station 16
(15' - 6" spacing)



Station 14

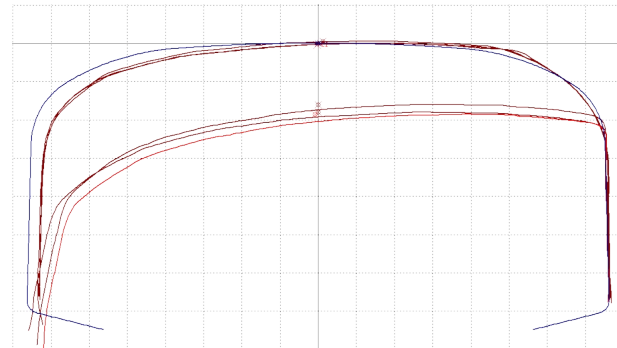
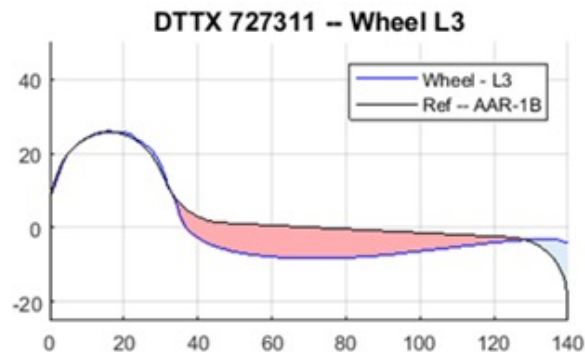


Station 11



Station 6

LET'S TAKE A CLOSER LOOK AT WHEEL PROFILES FROM B, C AND D TRUCKS, AND THEN RAIL PROFILES



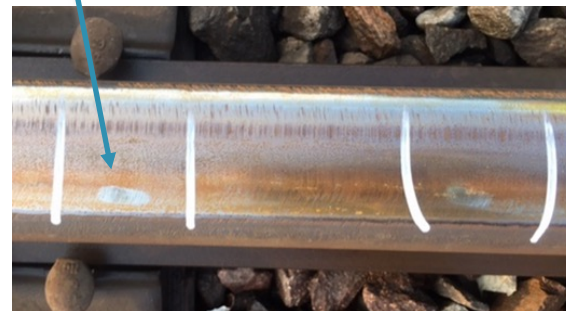
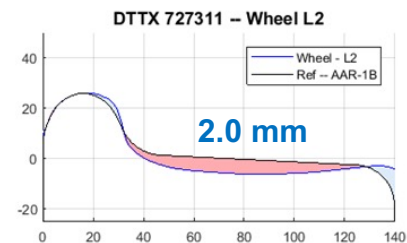
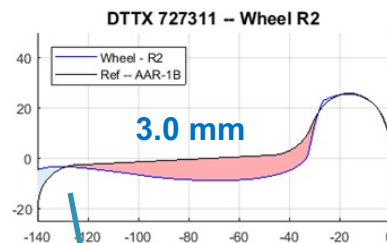
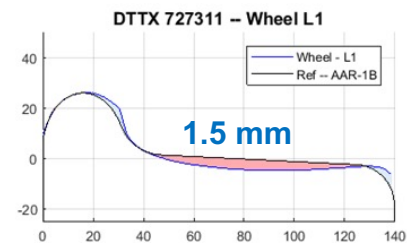
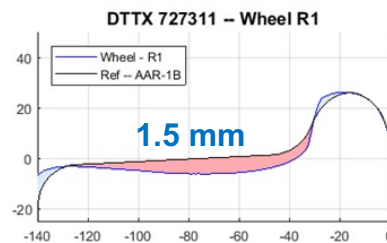
WHEEL PROFILES B TRUCK



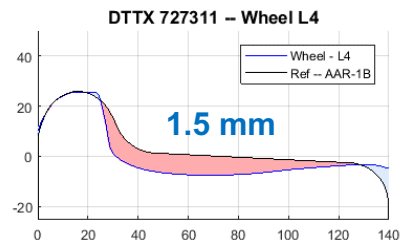
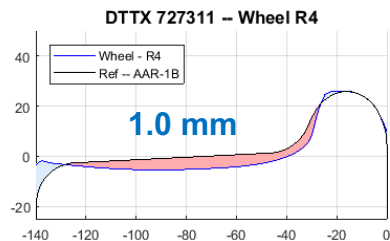
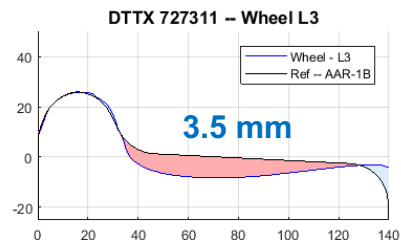
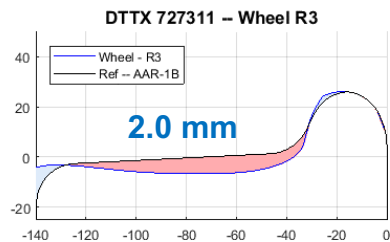
Low rail



High rail



WHEEL PROFILES C TRUCK



Low rail



High rail



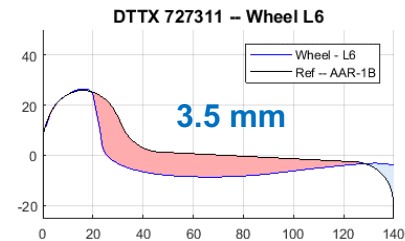
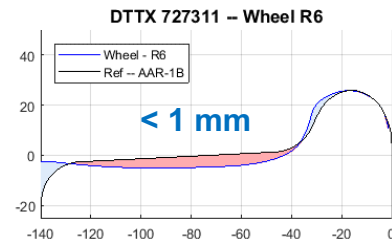
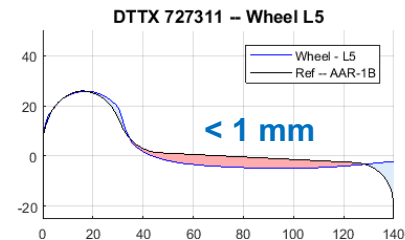
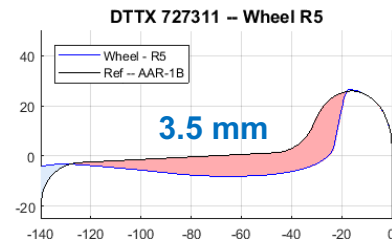
WHEEL PROFILES D TRUCK



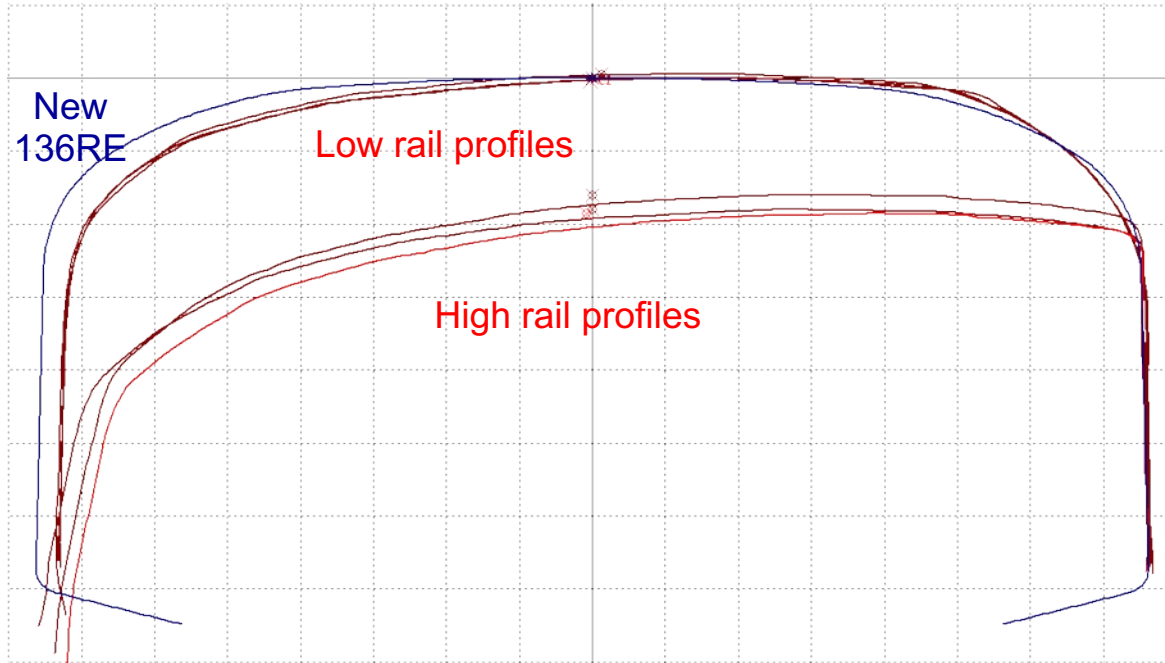
Low rail



High rail



RAIL PROFILES



High and low rail profiles from 3 locations in the full body (gage is on right).

The blue line is new 136RE.

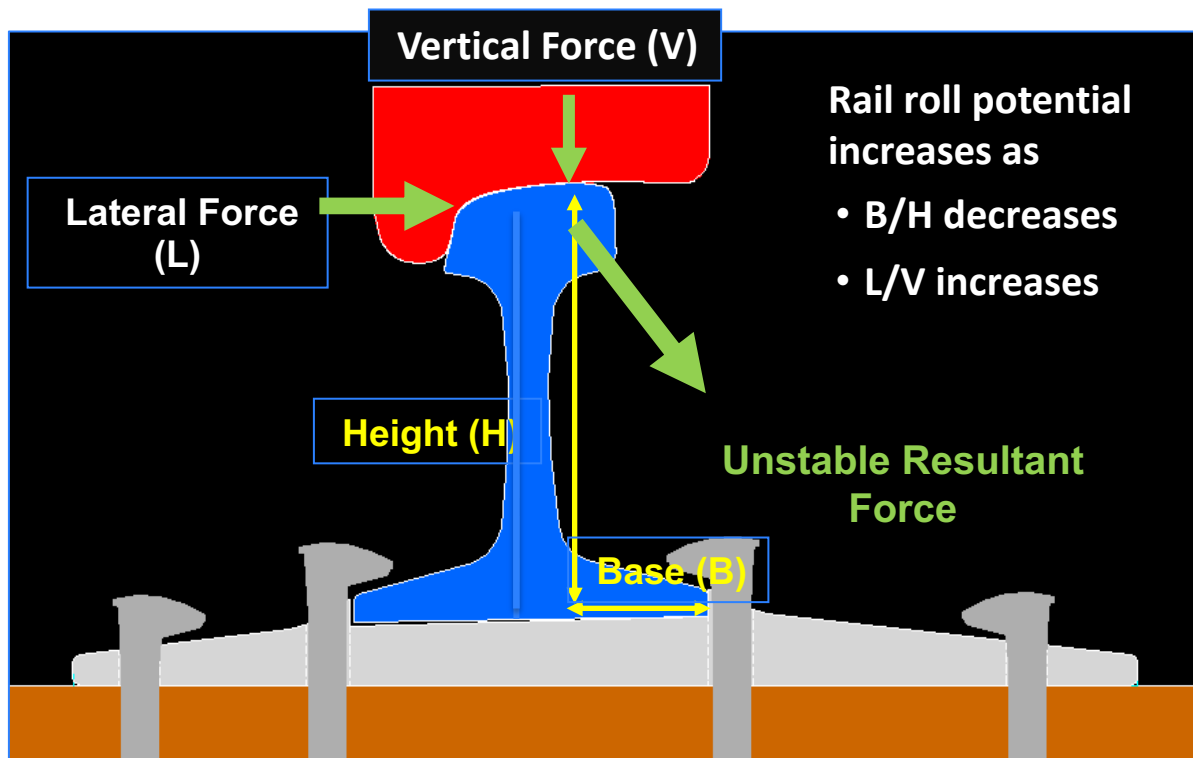
CAN A HIGH RAIL PROFILE CONTRIBUTE TO RAIL ROLLOVER?

Vertical force shifted toward the field side +

increased lateral force due to poor truck steering.....

produce a resultant directed outside the rail base.

This is an unstable condition - an unrestrained rail will tend to roll outward.



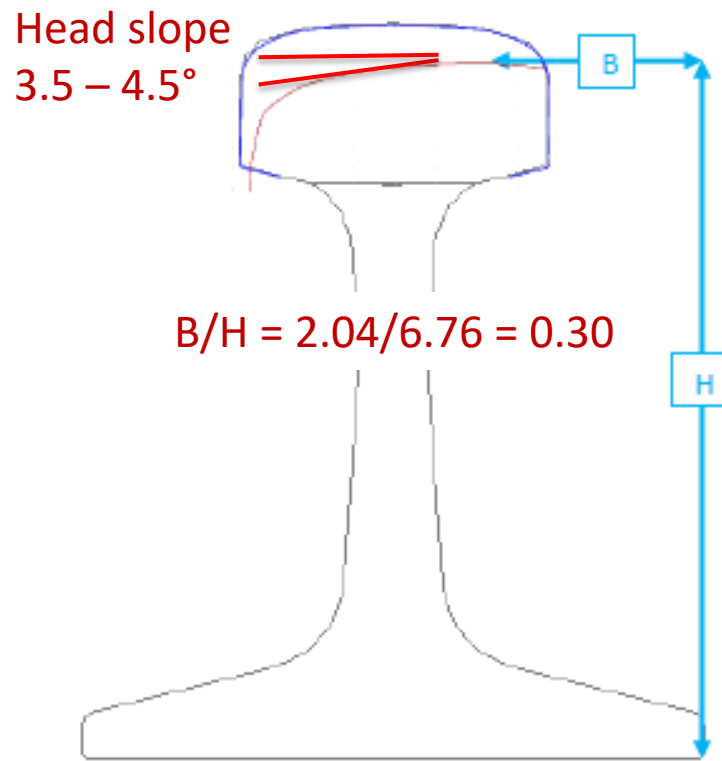
HOW DID WE EVALUATE THIS HIGH RAIL PROFILE?

We look at two geometric measurements:

- B/H (base/height) ratio, which is the base extension divided by rail height
- Head slope, which is defined by a line through two points ½" either side of centerline

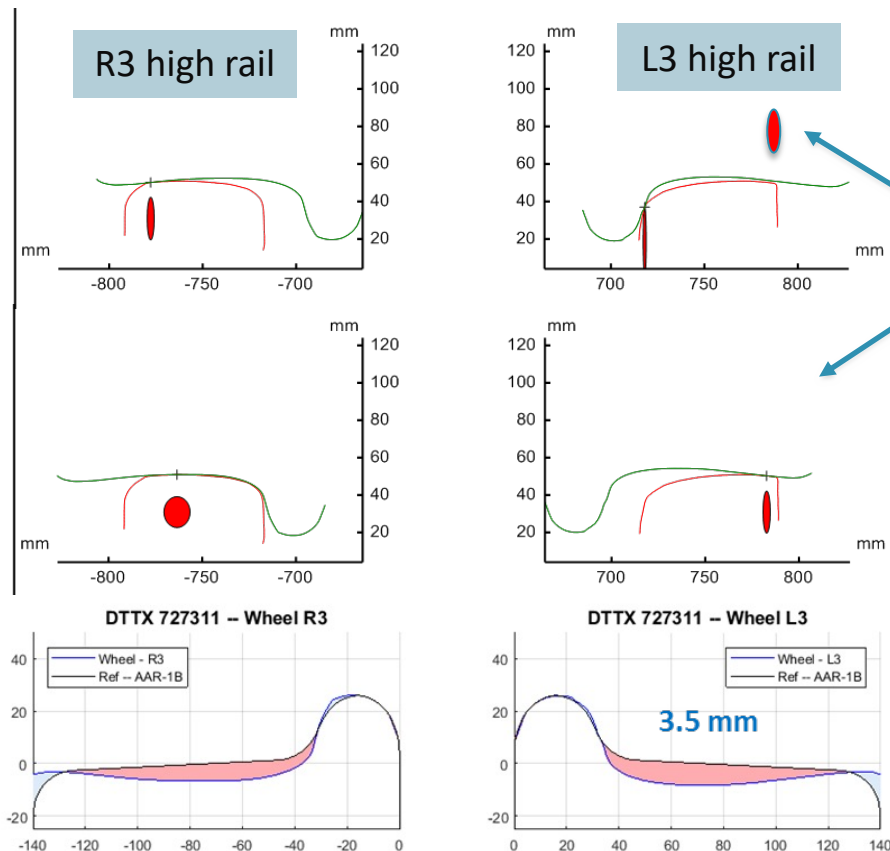
A B/H ratio of 0.30 means that the truckside L/V ratio need only exceed 0.30 to initiate rail roll!

Actual wheel contact location is influenced by B/H, head slope, rail cant and wheel profile.



High rail profile from near POD

VAMPIRE WHEEL/RAIL CONTACT PLOTS – C TRUCK, R3 & L3 WHEELS

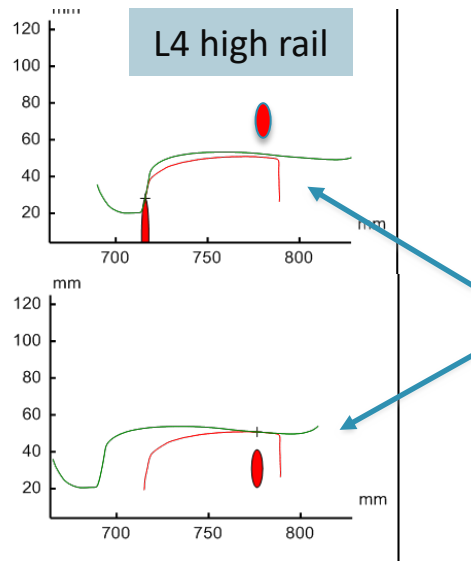
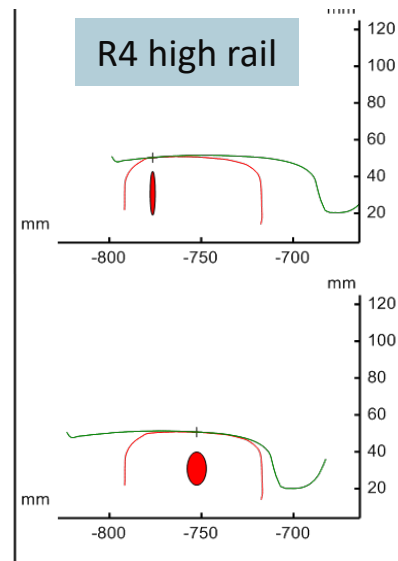


In all tracking positions – from high rail flanging to low rail flanging, the L3 wheel always contacts the field edge of the high rail. (Field side contact is typical of tread-hollow wheels.)

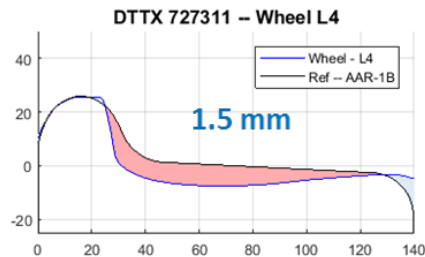
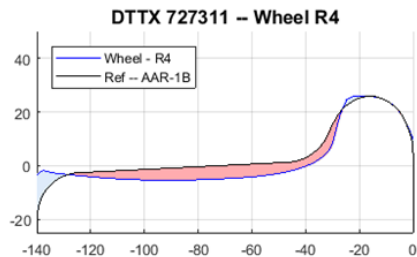
Consequences of this type of contact:

- ▶ high gage-spreading forces
- ▶ low B/H rail stability

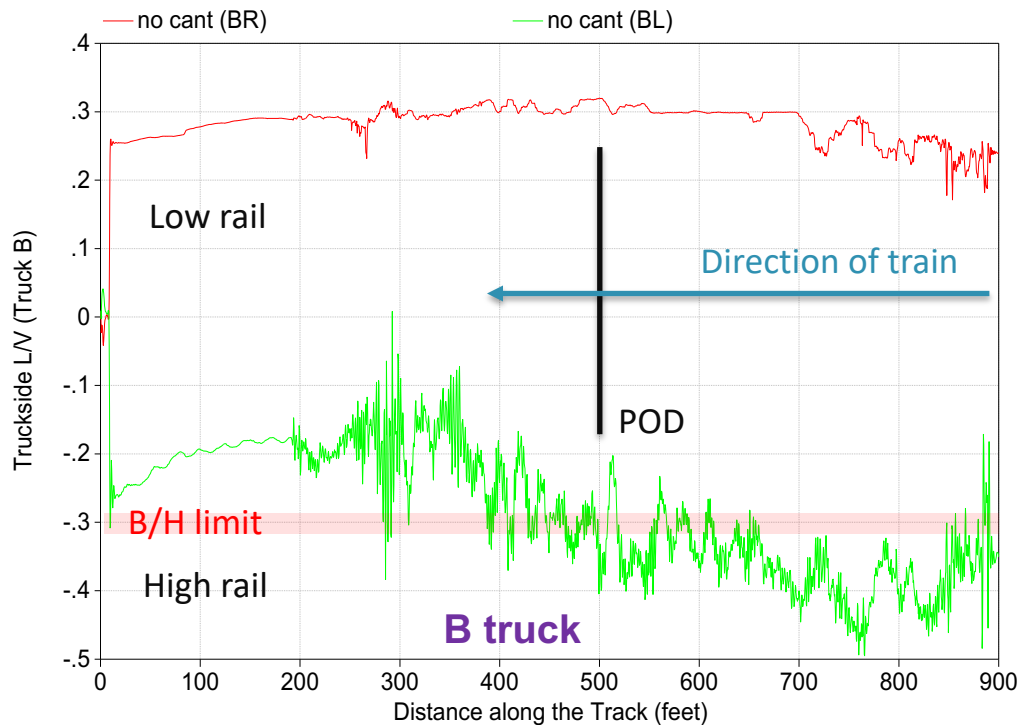
VAMPIRE WHEEL/RAIL CONTACT PLOTS – C TRUCK, R4 & L4 WHEELS



Like the L3, the L4 wheel always contacts the high rail on the field edge, no matter what the tracking position.



VAMPIRE TRUCKSIDE L/V RATIOS FOR B TRUCK



File 1: v1141.lis

Truckside L/V ratios are shown as a *function of cant*:

- red & green => no cant.

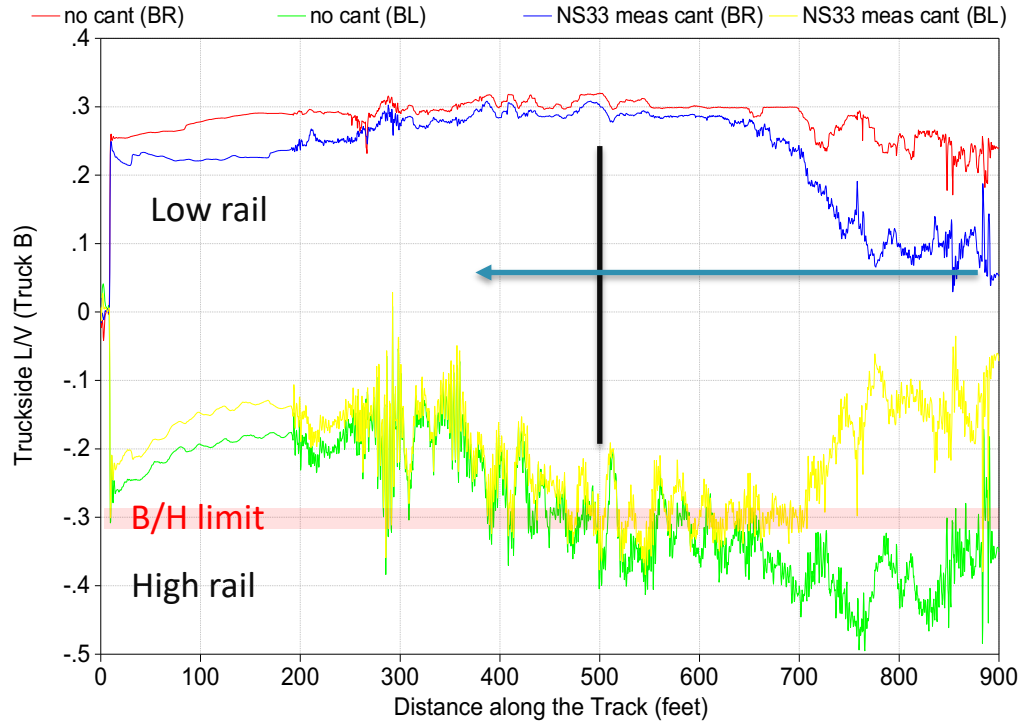
POD located at 500 feet

High rail L/V reaches 0.40 in the vicinity of the POD. But the rail hasn't rolled over yet!



How do we know?
Minimal damage to the B truck wheels

VAMPIRE TRUCKSIDE L/V RATIOS FOR B TRUCK



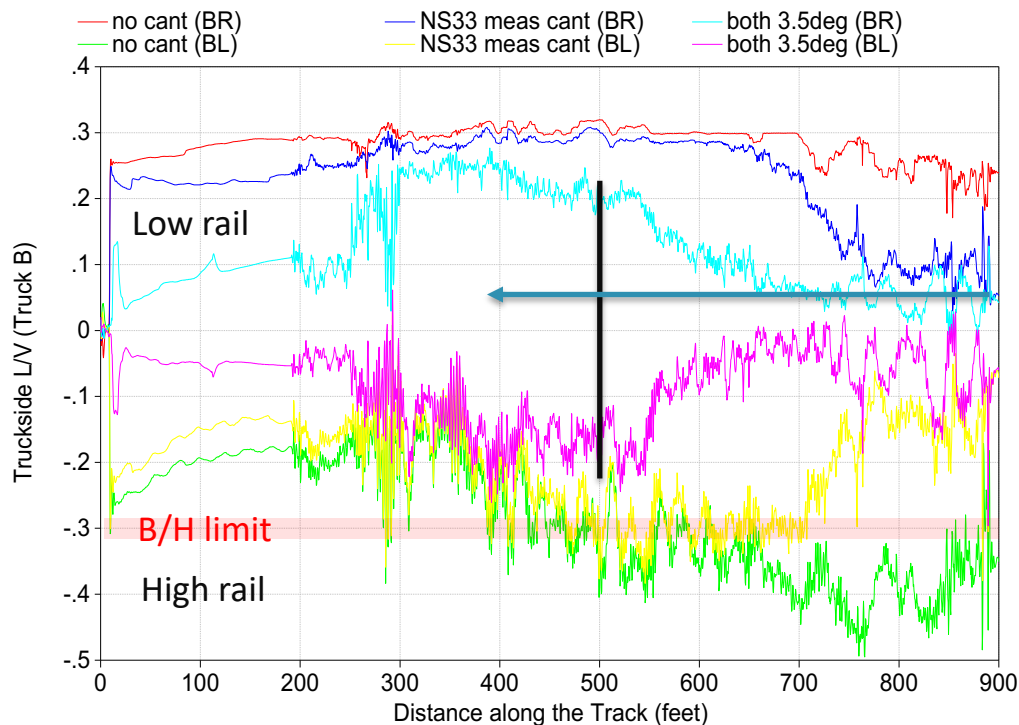
File 1: v1141.lis

File 2: v1151.lis

Truckside L/V ratios are shown as a function of cant:

- red & green => no cant
- blue & yellow => cant 0.5° high rail, 1.0° low rail (from April 2017 geo car)

VAMPIRE TRUCKSIDE L/V RATIOS FOR B TRUCK



File 1: v1141.lis

File 2: v1151.lis

File 3: v1171.lis

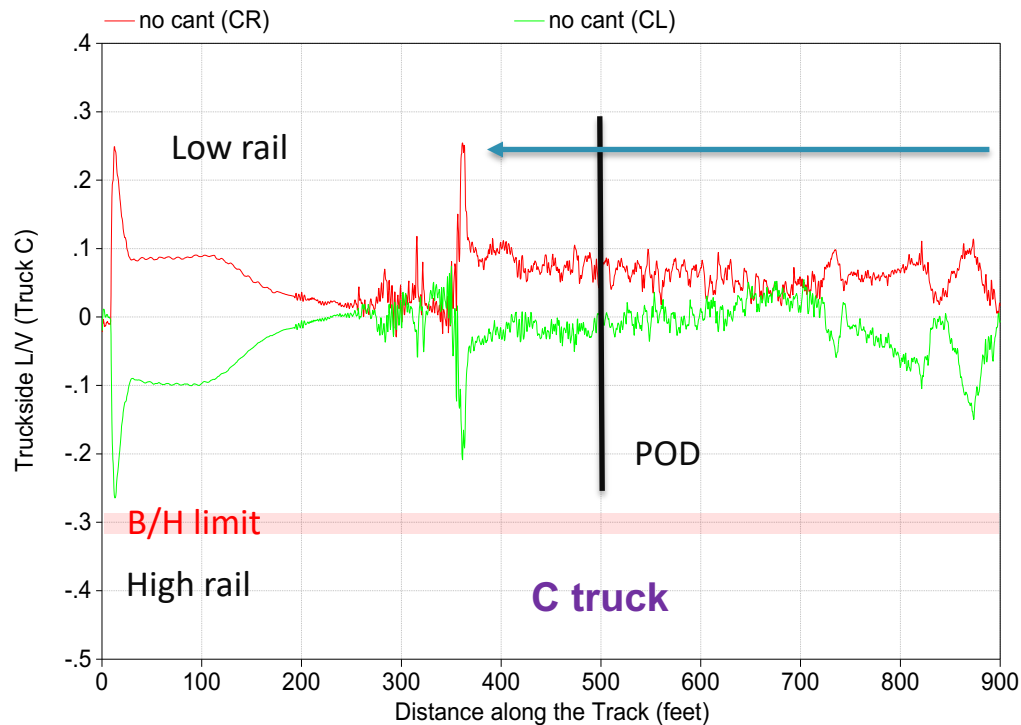
Truckside L/V ratios are shown as a function of cant:

- red & green => no cant
- blue & yellow => cant 0.5° high rail, 1.0° low rail (from April 2017 geo car)
- cyan & pink => 3.5° cant both rails (amount indicated by spike lift)

As cant increases, truckside L/V decreases!

There would likely be no derailment if B truck were the only consideration.

VAMPIRE TRUCKSIDE L/V RATIOS FOR C TRUCK

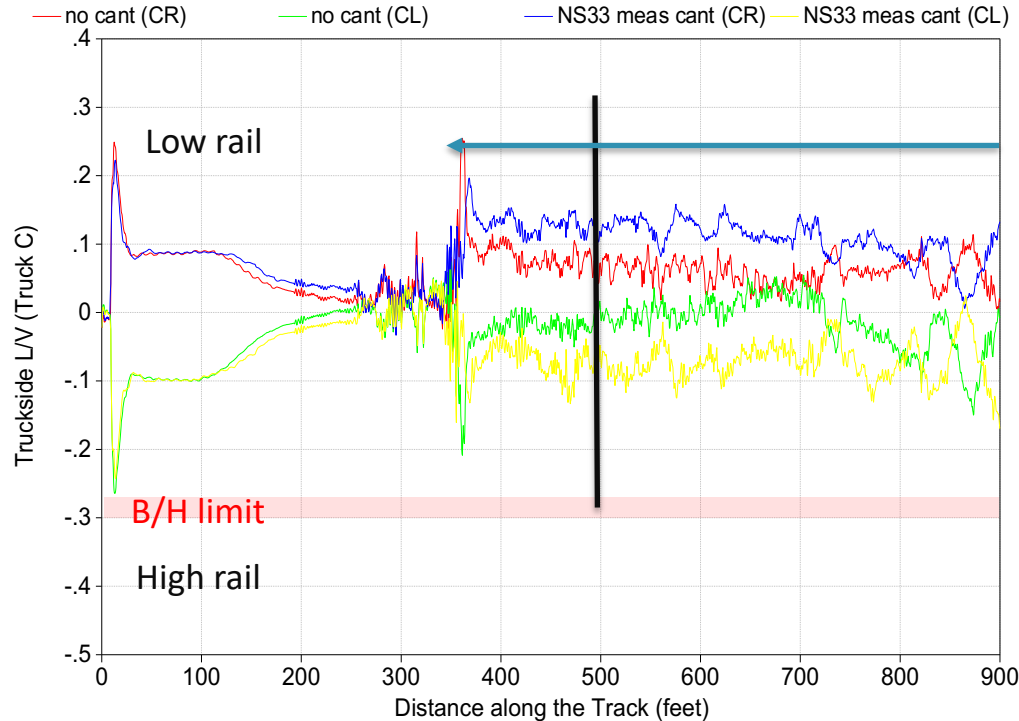


Truckside L/V ratios are shown as a function of cant:

■ red & green => no cant

POD located at 500 feet

VAMPIRE TRUCKSIDE L/V RATIOS FOR C TRUCK



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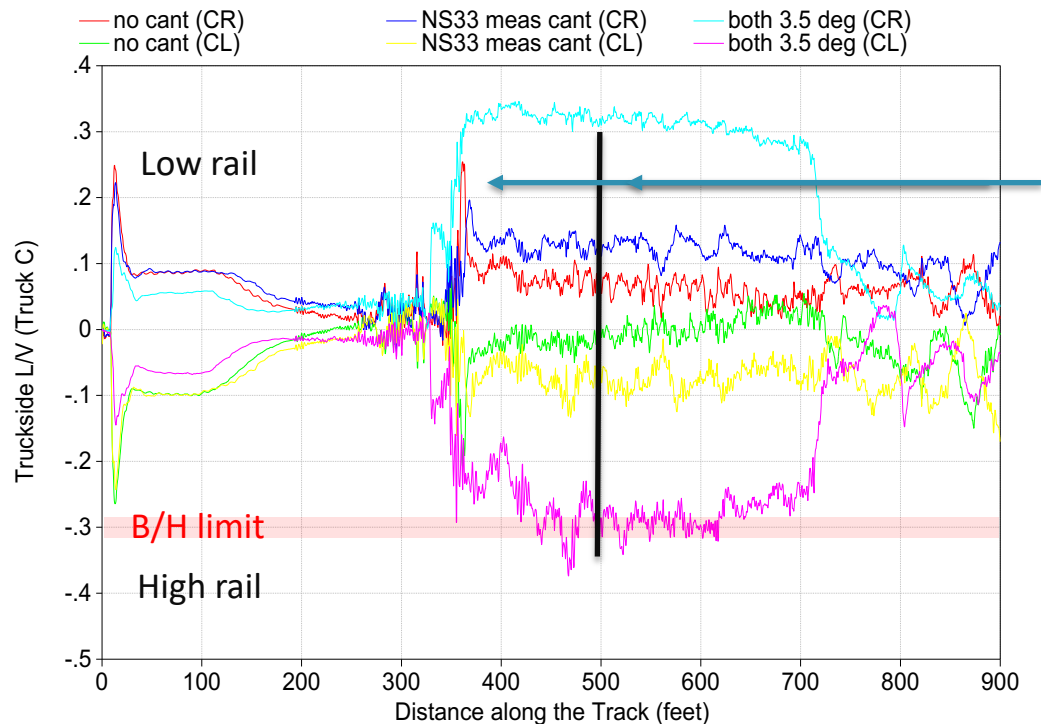
File 2: v1151.lis

Truckside L/V ratios are shown as a function of cant:

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As cant increases, truckside L/V also increases

VAMPIRE TRUCKSIDE L/V RATIOS FOR C TRUCK



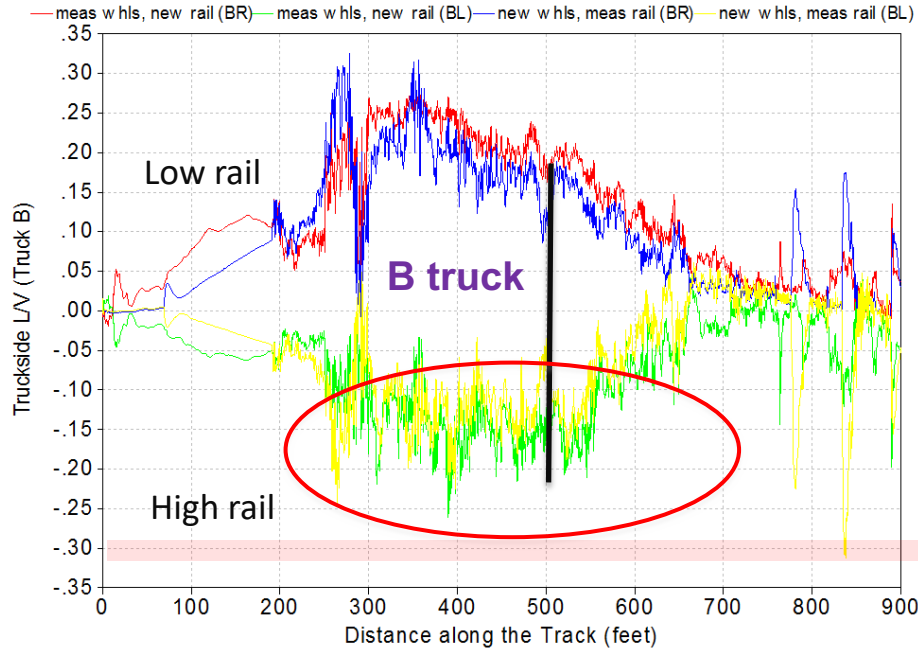
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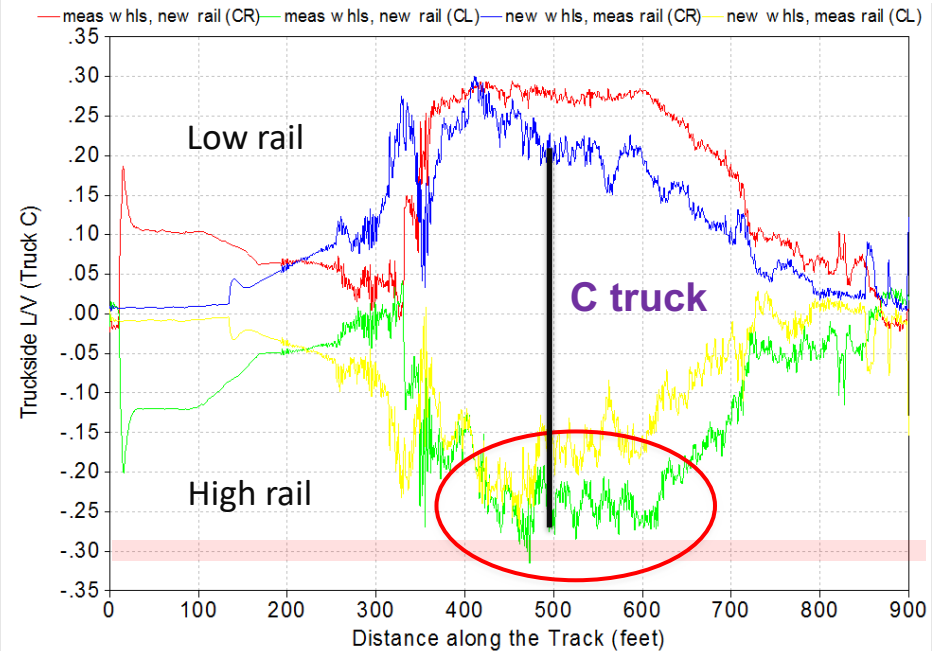
As cant increases, truckside L/V also increases, reaching a high rail L/V close to 0.35. This is self-driving behavior - as cant increases, B/H diminishes!

Conclusion: B truck initiated high rail cant, and then C truck rolled the rail over.

WHICH HAD GREATER IMPACT – WORN RAIL OR WORN WHEELS?



Red / green => worn wheels on new rail are = to
Blue / yellow => new wheels on worn rail



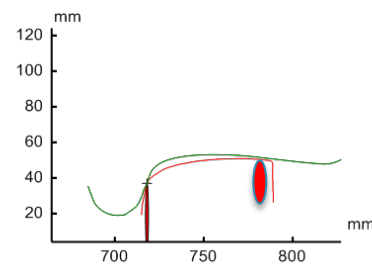
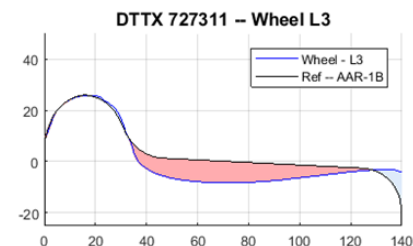
Red / green => worn wheels on new rail are > than
Blue / yellow => new wheels on worn rail

DERAILMENT CAUSE

Based on the truckside L/V ratios predicted by VAMPIRE, and the fact that the worn wheel profile had a greater impact than the worn rail profile:

“High rail rolled out under lead and intermediate trucks of loaded articulated doublestack DTTX 727311 account significantly hollow (but non-defective) wheel profiles operating on a high rail in a 3.5° curve with moderate head slope and low B/H.”

FRA Cause Code: E65C Worn Tread



WHAT IS UNIQUE ABOUT MULTI-PLATFORM DOUBLESTACK CARS?



Elevated truckside L/V under an articulated intermediate truck are particularly dangerous because.....

there is no adjacent truck applying a vertical load to hold down the rail.

QUESTIONS?

